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(56) Documents cited

GB A 2073775 GB A 2073249 GB A 2022137 GB 1274465 GB 1269342 GB 1236698

GB 1294336 (58) Field of search

GB 1230038

(58) Field of search **C7A**

(54) Process for preparing a high strength stainless steel material having excellent workability and free from weld softening

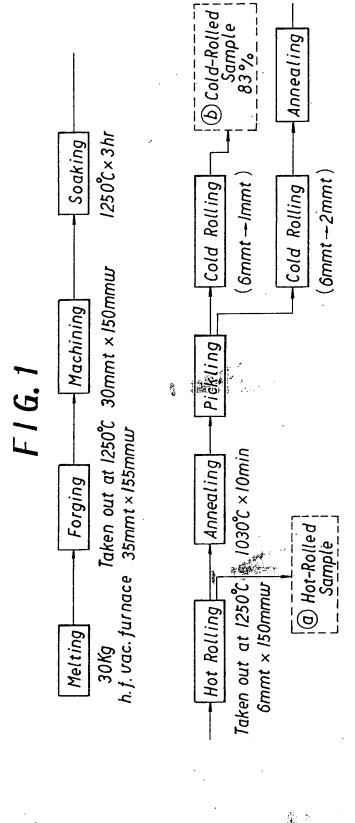
(57) A stainless steel which exhibits substantially martensitic structure at room temperature is heated at a temperature of 550 to 675°C for 1 to 30 hours. A reverse-transformed austenite phase appears and a stainless steel having high strength and high elongation and being free from weld softening is obtained.

The composition of the steel lies within the range:

Up to 4% in total of Cu, Mo, W and Co may be present with up to 1% in total of Ti, Nb, V, Zr, Al and B. The relationship

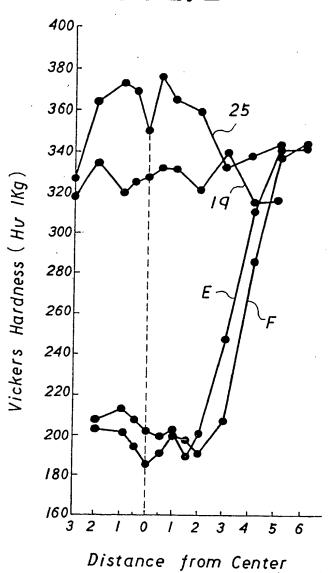
$$Ni_{eq} = 13.0 \text{ to } 17.5 = Ni + Mn + 0.5G + 0.3Si + 20[C + N]$$

must also be satisfied.



d Annealed Sample | Pickling 1030°C×15min Annealing © Cold Rolled Sample 50 % (2mmt-Immt) Cold Rolling **Pickling**

F1G.2



Distance from Center of Bead (mm)

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SPECIFICATION

Title of the Invention

Process for preparing a high strength stainless steel material having excellent workability and free from weld 5 softening

Field of the Invention

This invention relates to a high strength stainless steel material having excellent workability and resistance to softening by welding.

Background of the Invention

Conventional high strength stainless steels are roughly classified into (1) martensitic stainless steels, (2) work-hardenable austenitic stainless steels, and (3) precipitation-hardenable stainless steels.

Martensitic stainless steels mainly comprise Fe-Cr-C system and are substantially of single austenitic phase at 15 the quenching temperature (which is 900-1100°C, but varies depending on the content of Cr and C), but their martensite start point (Ms point) is higher than the room temperature range and they are so-called quench-hardenable steels.

These steels are hard and poor in workability in the quenched state or the quenched and tempered state. Therefore, in these steels, working such as bending, machining and cutting is carried out in the annealed state 20 and high strength is provided by a heat-treatment such as quenching and tempering after the steel is shaped as desired. However, heat-treatment of large parts or members is difficult, and these steel materials are susceptible to weld cracking, and, therefore, tempering must be carried out after welding.

When martensitic stainless steels are to be used as structural members, the above-mentioned defects must be compensated for. To this end, a steel in which the C content is restricted lower so that a massive martensite 25 phase appears in the quenched state has been considered. The steel of Japanese Patent Publication No. 51-35447 (1976) is an example of such a steel. A steel which falls within the claim of said patent publication is presented in No. 33 of "Nisshin Seiko Giho (Technical Reports of Nisshin Steel Co.)" (December 1975 issue). The composition thereof is: C: 0.032 %, Si: 0.75%, Mn: 0.14%, Ni: 4.01%, Cr: 12.4%, and Ti: 0.31%. This material has a tensile strength of about 108 kgf/mm² and an elongation of about 6%, and that is very low in weld 30 softening. Although low weld softening and fightensile strength are desirable for a welded structural material, the steel is still unsatisfactory as a structural material to be worked since elongation is poor and cracking easily occurs even in light working.

Work-hardenable austenitic stainless steels have the metastable austenitic phase as represented by AISI 301, 201, 304, 202, etc., and are hardened by cold working. Mechanical properties attained by this cold working are 35 stipulated in JIS G 4307. For instance, in 1/2H of AISI 301, it is specified that yield strength is not less than 77 kgf/mm², tensile strength is not less than 105 kgf/mm² and elongation is not less than 10%. That is, both tensile strength and elongation are specified as being high. However, the materials of this class have a defect in that when they undergo heat input such as welding, the heated part or weld softens. Also in some cases, chromium carbide deposit in the part heated by welding, and chromium-poor layers are formed and thus intergranular stress 40 corrosion cracking occurs.

Precipitation-hardenable stainless steels are classified into martensite type, ferrite type and austenite type in accordance with the structure of the matrix. But all of them contain at least one of A1, Ti, Nb, Cu, Mo, V, etc., which contribute to age-hardening, and the steels are hardened by precipitation of intermetallic compounds caused by aging from the super-saturated solid-solution state. These steels have a tensile strength of 140 - 190 45 kgf/mm² and an elongation of 2 - 5%, depending upon the state of the matrix, contents of the elements which contribute to age-hardening, etc.

When these steels are used for structural members, generally working and welding are effected prior to age-hardening. However, it is difficult to age-harden larger structural members.

As has been described, the materials conventionally known as high strength stainless steels do not possess all 50 of strength, workability and resistance to weld softening.

The object of the present invention is to provide a novel high strength steel material free from the above-described defects. The object is achieved by heating a steel material of a martensitic structure, which is in a specific composition range and that satisfies a specific composition relationship, to cause reverse austenitic transformation and stabilize the thus formed reverse-transformed austenite phase.

Summary of the Invention

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This invention provides process for preparing a high strength stainless steel material having excellent workability free from weld softening consisting of a single martensitic phase or a duplex phase structure of martensite and minute austenite, said process comprising heat-treating at a temperature of 550 to 675°C for 1 to 60 30 hours a hot-rolled, cold-rolled or annealed material of a steel essentially consisting of:

C: not more than 0.10%

Si: 0.20 - 4.5% Mn: 0.20 - 5.0%

P: not more than 0.060%

65 S: not more than 0.030%

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Cr: 10.0 – 17.0% Ni: 3.0 – 8.0%

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N: not more than 0.10%

and Fe and inevitable incidental impurities, wherein the Ni_{eq} value defined as:

 $5 \text{ Ni}_{eq} = \text{Ni} + \text{Mn} + 0.5\text{Cr} + 0.3\text{Si} + 20(\text{C} + \text{N})$ is in the range of 13.0 – 17.5

This invention also provides processes for preparing similar steel materials using steels which contain in addition to the above-described components not more than 4% in total of at least one of Cu, Mo, W, and Co and/or not more than 1% in total of at least one of Ti, Nb, V, Zr, A1 and B, wherein the definition of Ni_{eq} is modified in accordance with the composition.

10 When at least one of Cu, Mo, W and Co is contained, the Nieg value is defined as:

 $Ni_{eq} = Ni + Mn + 0.5Cr + 0.3Si + 20(C + N) +$

Cu + Mo + W + 0.2Co

When at least one of Ti, Nb, V, Zr, Al and B is contained, the Nieq value is defined as :

 $Ni_{eq} = Ni + Mn + 0.5Cr + 0.3Si$

When at least one of Cu, Mo, W and Co and at least one of Ti, Nb, V, Zr, Al and B are contained, the Ni_{eq} value is defined as:

 $Ni_{eq} = Ni + Mn + 0.5Cr + 0.3Si + Cu + Mo + W + 0.2Co$

The steel preferably contains 0.005 – 0.08% and more preferably 0.010 – 0.06% C; preferably 0.25 – 4.0% and more preferably 0.40 – 4.00% Si; preferably 0.30 – 4.50% and more preferably 0.40 – 4.0% Mn; preferably not more than 0.040% and more preferably not more than 0.025% P; preferably not more than 0.02% and more preferably not more than 0.015% S; preferably 11.0 – 16.0% and more preferably 12.0 – 15.0% Cr; preferably 3.5 – 7.5% and more preferably 4 – 7.5% Ni; preferably not more than 0.07% and more preferably not more than 0.05% N; preferably 0.5 – 3.5% and more preferably 1.0 – 3.0% of at least one of Cu, Mo, W and Co when contained; and preferably 0.1 – 0.8% and more preferably 0.15 – 0.8% of at least one of Ti, Nb, V, Zr, Al and B when contained.

The above-mentioned steel for the process of the present invention exhibits substantially martensitic structure in any of the hot-rolled state, cold-rolled state and annealed state, as a result of adjusting the composition so that the Ni_{en} value as defined above is in the above-defined range.

This invention is based on the inventors' finding that the above-mentioned steel, as hot-rolled, as cold-rolled 30 or as cold-rolled and annealed, undergoes reverse austenitic transformation and stabilized by heat-treating the steel at a temperature of 550 – 675°C for 1 – 30 hours. The mechanism involved and reason for it are not yet well understood, but it has been confirmed that this reverse austenitic transformation occurs with reproducibility. Modification of the properties of stainless steel of martensitic structure by such a treatment has never been attempted before.

The steel material of the present invention exhibits a strength level of about 100 kgf/mm² and an elongation of about 20%, and does not suffer from weld softening.

The reason why the composition of the steel is defined in the claim in the present invention is as follows:

C: C is an austenite former, and effective for formation of austenite phase at high temperatures, and is also effective for strengthening the reverse transformed austenite phase and martensite phase after the heat treatment.

40 However, a larger amount of C impairs elongation, and deteriorates corrosion resistance of the weld. Therefore, it is limited to 0.10%.

N: Like C, N is an austenite former, effective for formation of the austenite phase at high temperatures, and also hardens the reverse transformed austenite phase, and is therefore, effective for strengthening the steel. However, a larger amount of N deteriorates elongation. Therefore, N is limited to 0.1%.

45 Si: Si is effective for strengthening the reverse transformed austenite after the heat treatment and is effective for broadening the allowable temperature range for heat treatment. For this purpose, at least 0.2% Si is required. However, a large amount of Si promotes solidification cracking when the steel is solidified or welded. Therefore, the upper limit of the Si content is defined as 4.5%.

Mn: Mn is an austenite former and necessary for adjustment of the Ms point. For this purpose, at least 0.2% 50 Mn is required. But a larger amount of Mn causes troubles in the course of steelmaking and therefore its upper limit is defined as 5%.

Cr: Cr is a fundamental component for providing the steel with corrosion resistance. However, with less than 10%, no effect can be expected, while more than 17% of Cr requires a larger amount of austenite former elements in order to produce a single austenite phase at high temperatures. The upper limit of Cr is defined as 17% so that 55 the desired structure is obtained when the steel is brought to room temperature.

Ni: Ni is an austenite former, and is necessary for obtaining a single austenite phase at high temperatures and adjustment of the Ms point. The Ni content depends on the contents of the other elements. At least about 3% of Ni is required for obtaining a single austenite phase at high temperatures and adjustment of the Ms point. Even if the contents of the other elements are reduced, more than 8% of Ni does not give the desired structure.

P: P is an inevitable impurity element incidental to principal and auxiliary raw materials. P makes steels brittle and therefore it is limited to 0.060% at the highest.

S: S is also an inevitable impurity element incidental to principal and auxiliary raw materials in steelmaking. S also makes steels brittle and therefore it is limited to 0.030% at the highest.

Cu: Cu is inherently effective for improving corrosion resistance. In the present invention Cu is effective for 65 lowering the Ms point. However, if it is contained in an amount in excess of about 4%, workability at high

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temperature is impaired. Therefore, its content is limited to 4%.

Mo: Mo improves corrosion resistance and is effective for strengthening the reverse transformed austenite and lowering the Ms point. However, Mo is an expensive element and its content is limited to 4% in consideration of the cost of the steel.

W: W is effective for improving corrosion resistance and strength of the steel, and is also effective for lowering the Ms point. However, the upper limit is defined as 4%, since it raises the cost of the steel if it is contained in a larger amount.

Co: Co has a high austenitizing effect at the high temperature range, and lowers the Ms point. (Although this element has high austenitizing effect, it does not lower the Ms point excessively.) Co is very effective for 10 adjustment of composition in a high Cr content system. But the upper limit on the content thereof is defined as 4%, since it raises the cost of the steel if it is contained in a larger amount.

The last four elements mentioned above improve corrosion resistance and are effective for adjusting the martensite-forming ability of the steel in relation with the other components. They are equivalent in this sense.

Ti: Ti is a carbide-former and effective for preventing formation of Cr-poor layers caused by deposition of the carbide in welding and inhibition of grain growth of the reverse transformed austenite phase. However, if this is contained in a large amount, it may cause surface defects and may form a larger amount of scum in welding. Therefore, the Ti content is limited to 1%.

Nb: Nb is effective for preventing formation of Cr-poor layers caused by precipitation of Cr carbide in welding and inhibition of grain growth of the reverse transformed austenite phase. If it is contained in a larger amount, 20 however, it promotes solidification cracking when cast or welded, and also impairs ductility of the steel material. Therefore its content is limited to 1%.

V: V is effective for preventing formation of Cr-poor layers and inhibition of grain growth of the reverse transformed austenite. If it is contained in a larger amount, however, it impairs ductility of the steel. Therefore, its content is limited to 1%.

Zr: Zr is effective for preventing formation of Cr-poor layers caused by deposition of carbide in welding and inhibition of grain growth of the reverse transformed austenite phase. If it is contained in a larger amount, however, oxide type non-metallic inclusions are formed in casting and welding, and the surface properties and ductility of the steel are impaired. Therefore, its content is limited to 1%.

Al: Al has a remarkable effect for fixing N in the molten steel and inhibiting grain growth of the reverse 30 transformed austenite phase. If it is contained in a larger amount, it impairs flow of the molten metal in welding and thus makes the welding operation difficult. Therefore, the Al content is limited to 1%.

B: B is effective for inhibition of grain growth of the reverse transformed austenite and improvement of hot workability of the steel. If it is contained in a larger amount, however, it impairs ductility of the steel. Therefore, its content is limited to 1%.

The last six elements mentioned above are carbide formers, and remarkably effective in inhibiting grain growth of the reverse transformed austenite. In this sense, these six elements are equivalent.

The reason for defining the nickel equivalent (Ni_{ea}) as defined in the claims is as follows. In the steel used for

the present invention, the temperature at which the martensite transformation is finished must be around room temperature (150 – -10°C). The steel used in the process of the present invention is of single austenite phase in 40 the temperature range to which the steel is exposed during hot rolling, annealing or welding. But the steel must be substantially transformed into the martensite structure when the steel is brought down to room temperature from the above-mentioned condition. Here the term "substantially" means that a small amount (approximately 25%) of austenite may be retained. The amount of such remaining austenite need not be strictly considered.

In the steel used in the present invention, various elements are alloyed. We have found that insofar as the 45 composition of the steel falls within the above-described composition range and that the nickel equivalent (Ni_{eq}) thereof as defined above is in the above-described range, the steel is of substantially martensite structure at room temperature and the object of the invention as described in the beginning of this specification is achieved.

That is to say, even though the composition is within the above-defined range, if the nickel equivalent is less than 13, the Ms point is too high and the desired high elongation cannot be obtained even if the steel is

50 heat-treated as defined above. If the nickel equivalent is greater than 17.5, the steel softens at the weld when it is welded, and thus the desired high strength members cannot be obtained. Needless to say, the formula for Ni_{eq} was defined by considering the degree of contribution of each element to the austenite-martensite transformation and thus determining each coefficient as the equivalent of the Ni amount in comparison with the degree of the contribution of Ni. Ti and the five elements that follow are neutral with respect to the

55 above-described property, and that cancel the austenite-forming ability of C and N. Therefore, in the steels which contain these elements, these elements and C and N are not taken into consideration.

The reason for defining the heat treatment conditions as defined in the present invention is as follows: The steels which are of the martensite structure (massive martensite) in the annealed state have around 100

kgf/mm² of tensile strength. But as their elongation is about 6% at the utmost, it cannot be said that they have 60 satisfactory workability. When the steels are kept at a temperature in a range of 550 – 675°C for 1 – 30 hours so that part of martensite is reverse-transformed to austenite, the thus formed austenite is more or less stable as a structure, not all thereof returns to martensite in the cooling that follows, and may remain as austenite. At any rate, this heat-treatment confer high ductility to the steel without remarkably lowering strength (yield strength).

At temperatures lower than 550°C, the heat treatment does not effectively bring about this ductility, and at 65 temperatures higher than 675°C, yield strength as well as ductility are impaired.

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The time of the heat treatment is suitably selected by taking the size of the material to be treated into consideration. A heat treatment over 30 hours is disadvantageous since it raises the cost of the steel.

The steel material of the present invention is suitable for manufacturing structural parts and members as well as steel belt. The steel material possesses high strength, high ductility and does not suffer weld softening.

Now the invention will be explained specifically by way of working examples with reference to the attached drawings.

Brief Explanation of the Attached Drawings

Figure 1 is a flow chart illustrating preparation of samples in the present invention, and Figure 2 is a diagram 10 showing the softening at the weld in samples of the present invention and comparative examples.

Description of Specific Embodiments of the Invention

Sample steel heats were prepared using a vacuum high frequency furnace of 30 kg capacity by the usual process, and cast into ingots 110 × 110 mm at the bottom plane, 120 × 120 mm at the top plane and 290 mm 15 in height. The ingots were forged into plates 35 mm in thickness and 155 mm in width at 1250°C, and the plates were machined into plates measuring 30 mm × 150 mm. The plates were heated at 1250°C in a soaking pit and thereafter hot-rolled to 6 mm of thickness. A portion thereof was tested as hot-rolled samples (a), and the other portion was annealed at 1030°C for 10 minutes, pickled and cold-rolled into sheet of 1 mm thickness (83% reduction), a portion thereof was tested as cold-rolled sample (b). The remaining portion was cold rolled to 2

20 mm thick sheets and further cold-rolled after intermediate annealing to 1 mm thick sheets (50% reduction) and a portion thereof was tested as 50% reduction cold-rolled sheet samples (c). The remaining portion was further annealed at 1030°C for 1.5 minutes and pickled. These were tested as annealed samples (d). Procedures of preparing samples are illustrated in Figure 1.

The compositions of the samples of this invention and the comparative samples are indicated in Table 1.

25 Sample Nos. 1 – 32 are steels used in the process of this invention and Nos. A – F are steels of comparative examples. The compositions of these samples are within the defined composition range, but the nickel equivalent Ni_{eq} of Samples A – D are less than 13 and those of Samples E – F is greater than 17.5.

Mechanical property tests were carried out using test pieces No. 5 and No. 13B stipulated in JIS Z 2201. The amount of martensite was measured using a vibrating sample magnetometer.

Mechanical properties and the amount of martensite of the samples are summarized in Table 2. In Table 2, "Conventional Process" means that the heat treatment in accordance with this invention was not carried out. According to Table 2, the steels which were not heat-treated in accordance with the present invention and exhibit a substantially massive martensite structure in the annealed state have high level strength such as yield strengths of 73 – 126 kgf/mm² and tensile strengths of 94 – 135 kgf/mm², but their elongation is at the utmost

35 7.0%. This is remarkably low in comparison with Sample E and F, which are 20% cold-rolled sheets. Even among the samples which underwent the heat treatment of the present invention, those of the comparative steels have only 8.5% elongation at the highest, though even this is some improvement. The samples of the present invention exhibit generally remarkable improvement in elongation while retaining yield strength, although some samples suffer slight decrease in yield strength.

The mechanical properties and the amounts of martensite when annealed samples (d) were heat-treated under various conditions are shown in Table 3. "Comparative Process" in Table 3 means examples in which samples were heat-treated at temperatures in excess of the heat treatment temperature range of the present invention. From Table 3, it is learned that there is a criticality around the upper limit heat treatment temperature of 675°C.

The welding test was carried out by laying a bead on 1 mm thick plates by TIG welding with 50 A electric 45 current at a rate of 400 mm/min. The results are shown in Figure 2. Figure 2 shows hardness distribution profile from the center of beads. Sample 19 and 25, which are samples of the present invention, were heat-treated at 600°C for 20 hours. Comparative Sample E and F are 20% cold-rolled sheets. As seen in this figure, the samples of the present invention obviously do not exhibit softening at the weld.

TABLE 1

Chemical Composition and Ni_{eq} of the Steels for the Invention Process and Comparative Steels

P. S. Cr. Nii. N. Cu, Mo, Co, W. Zr, B, V. 0.027 0.009 12.96 3.52 0.012 0.029 0.010 13.04 4.00 0.076 0.029 0.010 13.04 4.00 0.076 0.029 0.014 13.03 6.52 0.012 0.021 0.009 16.99 5.01 0.015 Ccr. 3.01 0.021 0.009 16.99 5.01 0.015 Ccr. 3.01 0.029 0.017 13.04 7.7 0.014 Wr. 1.84 0.029 0.013 1.29 6.09 0.013 Mrc. 260 0.020 0.024 0.035 1.289 0.014 Crr. 2.12 0.027 0.006 1.287 0.019 Crr. 0.76 Wr. 1.08 0.028 0.013 1.004 Crr. 0.76 Wr. 1.08 Tr. 0.06 0.029 0.013 0.014 Crr. 0.76 Wr. 1.08 Tr. 0.16 0.020 0.012 0.013 0.014	i		:		;		Com	Composition (wt%)			Ti, Nb, Al,	
0.009 12.96 3.52 0.012 0.010 13.04 4.00 0.076 0.010 13.04 4.00 0.076 0.011 13.04 13.03 6.25 0.013 0.012 15.09 6.03 0.013 Mo: 2.12 0.007 12.91 7.47 0.013 Mo: 2.60 0.007 12.91 7.47 0.013 Mo: 2.60 0.004 13.82 7.12 0.013 Mo: 2.60 0.005 12.87 3.03 0.013 Mo: 2.60 0.006 12.87 3.03 0.013 Mo: 2.60 0.007 13.04 7.38 0.013 Mo: 2.60 0.008 12.89 6.67 0.020 Mo: 0.60 0.010 13.04 7.38 0.015 Mo: 0.41 0.006 14.08 6.60 0.027 Mo: 0.42 0.007 13.04 7.03 0.014 Mo: 0.42 0.006 13.61 6.91	No.	ပ	:is	Mn	d.	S	ర	Ņ	<	Cu, Mo, Co, W	Zr, B, V	Nieq
0,010 0,27 1,14 0,031 0,010 0,076 0,010 0,27 1,14 0,031 0,003 12,7 3 0,019 0,021 0,22 0,33 0,024 0,004 12,7 0,019	-	0.060	0.25	1.58	0.027	600.0	12.96	3.52	0.012			13.1
0.045 0.25 0.35 0.029 0.007 12.77 743 0.019 0.045 0.25 0.35 0.029 0.007 12.77 743 0.019 0.051 0.54 0.47 0.021 0.009 16.99 6.01 0.015 Cc. 3.01 0.051 0.24 0.47 0.021 0.009 16.99 6.01 0.015 Cc. 3.01 0.007 0.22 0.30 0.024 0.005 12.37 6.99 0.010 Cu. 2.12 0.008 0.22 0.30 0.024 0.005 12.37 6.99 0.019 Cu. 0.06 0.019 0.014 0.28 0.38 0.025 0.004 12.87 0.004 0.019 0.015 0.24 0.38 0.025 0.004 12.89 0.005 0.019 0.014 0.28 0.38 0.025 0.004 12.99 4.98 0.015 Tri. 0.16 0.015 0.25 2.87 0.020 0.005 12.99 4.98 0.015 Tri. 0.16 0.014 0.29 0.39 0.025 0.007 13.04 7.31 0.014 Tri. 0.28 0.015 0.30 0.027 0.004 12.90 0.005 0.005 13.04 0.015 Tri. 0.16 0.016 0.35 0.020 0.001 15.29 6.07 0.020 0.015 Tri. 0.015 0.017 0.30 0.30 0.020 0.001 15.29 6.07 0.020 0.016 0.018 0.35 0.020 0.001 15.29 0.006 13.04 0.015 Tri. 0.010 0.019 0.41 0.40 0.020 0.001 13.04 0.001 0.016 Tri. 0.020 0.001 0.020 0.41 0.40 0.020 0.001 13.04 0.001 0.016 Tri. 0.020 0.000 0.020 0.41 0.40 0.020 0.001 13.04 0.001 0.016 Tri. 0.020 0.000 0.020 0.41 0.40 0.020 0.001 13.04 0.001 0.001 Cu. 1.01 Tri. 0.020 0.000 0.020 0.41 0.40 0.020 0.001 13.06 0.001 Cu. 1.01 Tri. 0.00 0.000 0.030 0.25 0.20 0.002 0.001 13.07 0.000 0.016 0.001 Tri. 0.32 All. 0.00 0.007 0.30 0.020 0.001 13.07 0.000 13.06 0.001 Cu. 1.01 Tri. 0.00 0.000 0.007 0.007 0.008 0.006 13.06 0.000 0.001 Cu. 1.01 Tri. 0.30 All. 0.00 0.007 0.007 0.008 0.006 13.06 0.000 0.001 Cu. 1.01 Tri. 0.00 0.000 0.007 0.007 0.008 0.008 13.06 0.000 0.001 Cu. 1.01 Tri. 0.00 0.000 0.007 0.007 0.008 0.008 13.06 0.000 0.001 Cu. 1.01 Tri. 0.00 0.00	~	0.010	0.27	1.14	0.031	0.010	13.04	4.00	0.076			13.5
0.0245 2.07 0.37 0.034 0.014 13.03 6.75 0.010 0.021 0.24 0.31 0.034 0.014 13.03 6.75 0.010 0.012 0.007 0.28 0.27 0.012 1.29 4.07 0.013 Mcc. 26 0.019 0.41 0.33 0.027 0.004 1.28 0.013 Mcc. 26 0.019 0.41 0.33 0.027 0.004 1.287 0.013 Mcc. 26 0.013 0.26 0.020 0.006 1.287 0.013 Mcc. 26 0.014 0.28 3.80 0.020 0.006 1.287 0.019 Mcc. 26 0.014 0.28 3.80 0.020 0.006 1.287 0.019 Mcc. 26 Mcc. 26 0.014 0.28 0.007 1.009 1.299 4.98 0.016 Mcc. 26 Mcc. 27 0.014 0.28 0.007 1.009 1.009 0.016 Mcc. 26	· .	0.013	0.22	0.36	0.029	0.007	12.77	7.43	0.019			14.9
0.021 0.54 0.47 0.021 0.029 5.69 5.01 0.015 Cc. 3.01 0.071 0.24 0.27 0.029 6.03 0.010 Cc. 2.12 0.070 0.28 0.27 0.019 0.007 1.287 7.49 0.011 W. 1.88 0.073 0.28 0.27 0.004 1.287 6.69 0.013 Mor. 260 0.013 0.28 0.20 0.006 1.287 6.69 0.013 Mr. 1.08 0.014 0.28 0.28 0.026 0.007 1.289 4.98 0.016 Mr. 1.08 0.014 0.28 0.026 0.007 1.304 7.31 0.016 Mr. 1.06 0.014 0.28 0.036 0.012 1.304 7.31 0.016 Mr. 1.06 0.014 0.28 0.037 0.002 1.287 0.01 Mr. 1.06 Mr. 1.06 0.014 1.28 0.038 0.014 1.421 7.02 0.016	4	0.045	2.07	0.37	0.034	0.014	13.03	6.25	0.012			14.9
0.011 0.24 0.31 0.029 0.012 15.09 6.03 0.010 Cu. 2.12 0.007 0.28 0.27 0.019 1.297 6.09 0.013 Mor. 260 0.019 0.41 0.33 0.027 0.004 13.82 7.12 0.014 Cu. 0.76 W. 184 0.019 0.41 0.33 0.027 0.004 13.87 3.03 0.019 Tr. 0.16 0.014 0.25 2.87 0.005 0.005 12.99 4.98 0.016 Tr. 0.16 0.034 2.15 0.009 12.99 4.98 0.016 Tr. 0.16 0.034 2.16 0.027 0.009 12.99 4.98 0.016 Tr. 0.16 0.034 2.16 0.03 0.027 0.004 13.87 0.016 Tr. 0.16 0.034 2.09 0.036 0.031 0.010 1.28 0.016 Tr. 0.16 Tr. 0.16 0.034 0.039 0.039 0.03	TO.	0.021	0.54	0.47	0.021	600.0	16.99	5.01	0.015	Co: 3.01		15.2
0.007 0.28 0.27 0.019 0.007 1.29 1.47 0.011 W: 1.84 0.006 0.22 0.30 0.024 0.005 1.23 6.69 0.013 Mo: 2.60 0.013 0.41 0.33 0.027 0.006 1.287 3.02 0.014 0.026 0.013 1.299 3.02 0.014 0.02 0.018 0.018 Tr: 0.07 Tr: 0.016 0.014 0.22 0.38 0.026 0.007 1.304 7.38 0.016 Tr: 0.016 Tr: 0.016 0.014 0.92 0.38 0.026 0.007 1.304 7.38 0.016 Tr: 0.016 Tr: 0.016 0.014 0.92 0.38 0.026 0.001 1.304 7.31 0.014 Tr: 0.016 Tr: 0.016 0.014 0.92 0.39 0.029 0.006 1.304 7.38 0.015 Tr: 0.016 Tr: 0.16 0.014 0.92 0.039 0.020 0.001 1.304	9	0.011	0.24	0.31	0.029	0.012	15.09	6.03	0.010	Cu: 2.12		16.5
0.006 0.22 0.33 0.024 0.004 1.33 6.69 0.013 Mor. 260 0.019 0.41 0.33 0.027 0.004 1.38 7.12 0.014 Cu. 0.76, W: 1.08 0.014 0.28 4.69 0.025 0.004 1.29 4.89 0.015 1.29 4.89 0.015 1.29 4.89 0.015 1.29 4.89 0.015 1.29 4.89 0.015 1.29 4.89 0.016 Tri 0.16 0.034 0.22 0.036 0.027 1.004 7.39 0.016 Tri 0.02 0.034 2.16 0.31 0.027 0.006 1.29 4.98 0.016 Tri 0.02 0.034 2.16 0.31 0.027 0.006 1.421 0.02 0.013 0.014 Mr. 0.49 0.02 0.035 0.30 0.026 0.014 1.387 7.00 0.013 Mr. 0.49 Mr. 0.74 0.026 0.011	7	0.007	0.28	0.27	0.019	0.007	12.91	7.47	0.011	W: 1.84		16.5
0.019 0.41 0.33 0.027 0.004 13.82 7.12 0.014 Cu. 0.76 W. 1.08 0.013 0.228 3.80 0.020 0.005 12.89 3.03 0.019 Tir. 0.27 0.014 0.28 4.89 0.035 0.033 12.99 4.98 0.015 Tir. 0.16 0.014 0.22 2.87 0.026 0.007 13.04 7.38 0.015 Tir. 0.16 0.014 0.22 0.38 0.026 0.007 13.04 7.38 0.015 Tir. 0.16 0.014 0.22 0.38 0.020 0.009 13.29 4.98 0.015 Tir. 0.16 0.024 0.36 0.017 13.04 7.33 0.013 Tir. 0.16 Tir. 0.16 0.026 0.85 0.03 0.014 14.21 7.02 0.013 Tir. 0.16 0.026 0.86 0.036 0.014 14.21 7.02 0.015 Tir. 0.015 0.027	œ	9000	0.22	0.30	0.024	0.005	12.37	69.9	0.013	Mo: 2.60		16.2
0.013 0.26 380 0.020 0.006 12.87 3.03 0.018 Tr. 0.27 0.014 0.25 2.84 4.69 0.036 0.036 12.90 4.98 0.018 Tr. 0.16 0.014 0.25 2.87 0.026 0.037 13.04 7.31 0.015 Tr. 0.16 0.014 0.25 2.87 0.026 0.037 13.04 7.31 0.015 Tr. 0.16 0.014 0.32 0.33 0.012 13.04 7.31 0.014 N.6 0.016 Tr. 0.16 0.026 0.85 0.30 0.017 13.04 7.31 0.013 Tr. 0.16 N.6 0.01 Tr. 0.16 N.6 0.01 N.6 0.01 N.6 0.01 N.6 0.01 N.6 0.01 N.6 0.02 0.01 N.6	ი	0.019	0.41	0.33	0.027	0.004	13.82	7.12	0.014	Cu: 0.76, W: 1.08	-	17.0
0.014 0.28 4.66 0.035 0.013 12.90 3.02 0.018 Tr. 0.16 0.034 0.28 0.022 0.009 1.299 4.98 0.015 Tr. 0.16 0.014 0.22 0.38 0.020 0.007 13.04 7.31 0.014 Tr. 0.16 0.014 0.32 0.38 0.020 0.007 1.004 7.31 0.014 Tr. 0.16 0.024 0.31 0.020 0.001 1.007 1.004 7.01 0.014 0.020 0.014 0.020 0.014 0.020 0.014 0.020 0.014 0.020 0.014 0.020 0.014 0.01 0.012 0.010 0.013 0.010 0.013 0.010 0.013 0.010 0.010 0.013 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010 0.010	0	0.013	0.26	3.80	0.020	900.0	12.87	3.03	0.019		ï	13.3
0.030 0.25 2.87 0.022 0.009 12.99 4.98 0.015 Tr. 0.08 0.014 0.92 0.33 0.026 0.007 13.04 7.38 0.015 Tr. 0.15 0.014 0.92 0.33 0.027 0.008 12.94 7.31 0.013 Tr. 0.15 0.026 0.85 0.30 0.012 1.00 1.62 6.94 0.013 Nb. 0.41 0.026 0.86 0.39 0.036 0.014 14.21 7.02 0.015 Tr. 0.28 0.016 0.32 0.036 0.014 14.21 7.02 0.015 Tr. 0.67 0.016 0.32 0.046 0.027 0.016 13.64 7.03 0.014 V. 0.47 0.016 0.32 0.046 14.61 7.03 0.014 V. 0.47 0.017 0.32 0.46 0.037 0.008 13.64 7.03 0.014 V. 0.47 0.017 0.32 0.038	_	0.014	0.28	4.69	0.035	0.013	12.90	3.02	0.018			14.2
0.014 0.92 0.38 0.026 0.007 13.04 7.38 0.015 Tr. 0.15 0.011 2.02 0.37 0.030 0.012 13.04 7.31 0.014 Tr. 0.28 0.023 0.031 0.010 15.26 6.94 0.013 NB. 0.20 0.024 0.37 0.030 0.014 14.21 7.02 0.015 NB. 0.24 0.020 0.86 0.39 0.031 0.010 15.62 0.015 NB. 0.42 0.014 0.37 0.026 0.014 14.21 7.02 0.016 NB. 0.42 0.015 0.32 0.026 0.004 13.87 7.03 0.016 NB. 0.72 0.010 0.35 0.026 0.001 13.57 0.016 NB. 0.42 0.010 0.35 0.026 0.001 13.57 0.04 NB. 0.42 0.011 0.30 0.028 0.006 13.51 6.99 0.010 NB. 0.42 0.020<	2	0.030	0.25	2.87	0.022	0.009	12.99	4.98	0.015			14.4
0.011 2.02 0.37 0.030 0.012 1.304 7.31 0.014 Tr. 0.28 0.034 0.134 0.036 0.012 1.304 7.31 0.013 Nb: 0.41 0.026 0.85 0.31 0.027 0.008 12.92 667 0.029 0.015 Nb: 0.42 Nb: 0.40 0.014 0.37 0.29 0.036 0.014 14.21 7.02 0.015 Nb: 0.50 0.015 0.29 0.036 0.014 14.21 7.02 0.016 B: 0.39 0.015 0.32 0.026 0.004 13.87 7.00 0.016 B: 0.39 0.016 0.32 0.026 0.011 13.74 7.03 0.014 Y: 0.47 0.011 0.30 0.028 0.006 13.64 7.03 0.010 Tr: 0.50 0.028 0.40 0.034 0.006 13.61 7.04 0.010 Tr: 0.50 0.028 0.42 0.028 0.006 </td <td>ლ</td> <td>0.014</td> <td>0.92</td> <td>0.38</td> <td>0.026</td> <td>0.007</td> <td>13.04</td> <td>7.38</td> <td>0.015</td> <td></td> <td></td> <td>14.6</td>	ლ	0.014	0.92	0.38	0.026	0.007	13.04	7.38	0.015			14.6
0.034 2.15 0.31 0.027 0.008 12.92 667 0.020 0.026 0.86 0.39 0.031 0.010 15.62 6.94 0.013 Nb: 0.50 0.027 0.38 0.39 0.036 0.014 14.21 7.00 0.015 Ti: 0.67 0.020 0.54 0.39 0.029 0.006 14.08 6.00 0.027 Al: 0.77 0.015 0.32 0.46 0.025 0.004 13.87 7.00 0.016 B: 0.39 0.010 0.32 0.46 0.025 0.004 13.64 7.00 0.016 R: 0.07 0.010 0.32 0.40 0.037 0.006 13.64 7.00 0.016 Ti: 0.04 0.028 0.41 0.02 0.006 13.64 7.00 0.010 Ti: 0.05 NB: 0.40 0.028 0.42 0.026 13.64 7.04 0.010 Ti: 0.02 NB: 0.40 NB: 0.42 0.026 NB:	4	0.011	2.02	0.37	0.030	0.012	13.04	7.31	0.014			14.8
0.026 0.85 0.30 0.031 0.010 1.62 6.94 0.013 Nb: 0.50 0.014 0.37 0.29 0.026 0.014 14.21 7.02 0.015 TI: 0.67 0.015 0.32 0.029 0.026 0.004 13.87 7.00 0.016 B: 0.37 0.015 0.32 0.46 0.025 0.004 13.64 7.03 0.014 V: 0.47 0.010 0.35 0.40 0.037 0.006 13.64 7.03 0.014 V: 0.47 0.011 0.30 0.226 0.011 13.72 6.89 0.010 TI: 0.50 Nb: 0.42 0.010 0.41 0.40 0.024 0.006 13.61 6.91 0.010 TI: 0.50 Nb: 0.42 0.026 1.30 0.022 0.011 13.72 7.04 0.010 TI: 0.10 V: 0.47 0.026 1.30 0.026 13.61 13.87 7.02 0.013 TI: 0.10	വ	0.034	2.15	0.31	0.027	0.008	12.92	6.67	0.020		Nb: 0.41	14.1
0.014 0.37 0.29 0.036 0.014 14.21 7.02 0.015 Ti: 0.67 0.020 0.024 0.039 0.029 0.006 14.08 6.60 0.027 Al: 0.77 0.010 0.32 0.046 10.03 0.006 14.08 6.60 0.027 Al: 0.77 0.011 0.32 0.44 0.025 0.006 13.87 7.00 0.014 V: 0.49 0.011 0.30 0.35 0.026 0.011 13.72 6.89 0.010 Ti: 0.50 Nb: 0.42 0.028 0.036 0.041 13.72 6.89 0.010 Ti: 0.50 Nb: 0.42 0.028 0.036 0.042 1.006 13.61 6.91 0.010 Ti: 0.50 Nb: 0.42 0.028 0.036 1.006 14.61 7.36 0.010 Ti: 0.10 V: 0.41 0.040 1.44 0.29 0.011 1.387 7.02 0.008 Cu: 0.68 Mo: 1.07 Ti: 0.49<	9	0.026	0.85	0.30	0.031	0.010	15.62	6.94	0.013		Nb: 0.50	15.3
0.020 0.54 0.39 0.029 0.006 14.08 6.60 0.027 Al: 0.77 0.015 0.026 0.025 0.004 13.87 7.00 0.016 B: 0.39 0.010 0.35 0.046 0.025 0.004 13.87 7.00 0.014 V: 0.47 0.011 0.30 0.35 0.026 0.011 13.72 6.89 0.010 Ti: 0.50 Nb: 0.42 0.028 0.034 0.006 13.51 6.91 0.010 Ti: 0.50 Nb: 0.42 0.028 0.029 0.006 14.61 7.36 0.013 Ti: 0.50 Nb: 0.42 0.029 0.021 0.006 14.61 7.36 0.013 Ti: 0.10 V: 0.25 0.029 0.028 0.006 14.61 7.36 0.013 Ti: 0.10 V: 0.41 0.029 0.031 0.021 0.006 14.61 7.36 0.013 Ti: 0.10 V: 0.25 0.039 0.221 0.012 <td>_</td> <td>0.014</td> <td>0.37</td> <td>0.29</td> <td>0.036</td> <td>0.014</td> <td>14.21</td> <td>7.02</td> <td>0.015</td> <td></td> <td>Ti: 0.67</td> <td>14.5</td>	_	0.014	0.37	0.29	0.036	0.014	14.21	7.02	0.015		Ti: 0.67	14.5
0.015 0.32 0.46 0.025 0.004 13.87 7.00 0.016 B: 0.39 0.010 0.35 0.40 0.037 0.006 13.64 7.03 0.014 V: 0.47 0.031 0.036 0.037 0.006 13.51 6.89 0.010 Tr: 0.50, Nb: 0.42 0.039 0.44 0.028 0.024 0.006 13.57 7.04 0.010 Tr: 0.50, Nb: 0.42 0.028 0.35 0.42 0.028 0.021 0.006 13.57 7.04 0.010 Tr: 0.50, Nb: 0.42 0.040 1.44 0.29 0.018 0.006 13.57 7.02 0.008 Tr: 0.10, Nb: 0.41 0.038 1.52 0.21 0.027 0.011 13.87 7.02 0.008 Cu: 0.68, Mo: 1.02 Tr: 0.10, Nb: 0.41 0.007 2.04 0.30 0.021 0.011 13.87 7.02 0.008 Cu: 0.68, Mo: 1.02 Tr: 0.10, Nb: 0.41 0.007 2.04 0.30 0.021	8	0.020	0.54	0.39	0.029	900.0	14.08	09'9	0.027		AI: 0.77	14.2
0.010 0.35 0.40 0.037 0.006 13.64 7.03 0.014 V: 0.47 0.011 0.35 0.026 0.011 13.72 6.89 0.010 Tr: 0.59 0.028 0.035 0.026 0.011 13.71 6.89 0.010 Tr: 0.50 0.028 0.035 0.028 0.006 13.57 7.04 0.010 Tr: 0.10 Tr: 0.10 0.036 1.90 0.039 0.011 13.87 7.02 0.003 Tr: 0.10 Tr: 0.10 Tr: 0.10 V: 0.25 0.040 1.44 0.29 0.011 13.87 7.02 0.008 Cu: 0.68 Mo: 1.02 Tr: 0.10 V: 0.25 0.007 3.06 0.31 0.021 0.011 13.87 7.02 0.008 Cu: 0.68 Mo: 1.17 Tr: 0.10 V: 0.25 0.007 3.06 0.31 0.021 0.012 12.18 5.40 0.011 Cu: 2.03 Mo: 0.45 0.010 2.04 <	9	0.015	0.32	0.46	0.025	0.004	13.87	7.00	0.016			14.5
0.011 0.30 0.35 0.026 0.011 13.72 6.89 0.010 Zr. 0.59 0.030 0.41 0.40 0.034 0.008 13.61 6.91 0.010 Tr. 0.50, Nb. 0.42 0.028 0.036 0.042 0.008 1.357 7.04 0.010 Tr. 0.50, Nb. 0.42 0.040 1.90 0.038 0.018 0.006 1.461 7.36 0.013 Tr. 0.10, Vr. 0.25 0.040 1.44 0.29 0.018 0.006 1.461 7.36 0.010 Tr. 0.10, Vr. 0.25 0.007 3.06 0.31 0.024 0.008 13.16 6.33 0.015 Mor. 1.77 Tr. 0.10, Vr. 0.25 0.007 2.04 0.30 0.022 0.012 12.18 5.40 0.011 Cu. 2.03 Nbr. 0.49 0.010 2.56 0.24 0.028 0.008 13.09 7.00 0.014 Cu. 2.03 Nbr. 0.45 0.010 2.56 0.24 0.028 0.008	2	0.010	0.35	0.40	0.037	9000	13.64	7.03	0.014			14.4
0.030 0.41 0.40 0.034 0.008 13.61 6.91 0.010 Tri. 0.50, Nb: 0.42 0.028 0.35 0.42 0.028 0.006 13.57 7.04 0.010 Tri. 0.50, Nb: 0.42 0.046 1.90 0.39 0.021 0.006 14.61 7.36 0.010 Cu: 1.01 Tri. 0.10, V: 0.25 0.040 1.44 0.29 0.018 0.006 14.61 7.36 0.010 Cu: 1.01 Tri. 0.10, V: 0.25 0.073 3.05 0.21 0.027 0.011 13.87 7.02 0.008 Cu: 0.68, Mo: 1.02 Tri. 0.10, V: 0.25 0.073 3.05 0.021 0.011 13.87 7.02 0.008 Cu: 0.68, Mo: 1.02 Tri. 0.10, V: 0.21 0.071 2.04 0.32 0.012 12.18 5.40 0.011 Cu: 2.03 Nb: 0.45 0.010 2.56 0.24 0.028 0.028 13.09 7.00 0.014 Cu: 0.91, W: 1.97 Tri. 0.58 0.046	5	0.01	0:30	0.35	0.026	0.011	13.72	6.83	0.010			14.1
0.028 0.35 0.42 0.028 0.006 13.57 7.04 0.010 Tri: 0.32, Ai: 0.50 0.056 1.90 0.39 0.021 0.005 13.06 6.25 0.013 Tri: 0.10, V: 0.25 0.040 1.44 0.29 0.018 0.006 1.461 7.36 0.010 Tri: 0.10, V: 0.25 0.038 1.52 0.21 0.027 0.011 1.387 7.02 0.008 Cu: 0.68, Mo: 1.02 Tri: 0.10, V: 0.25 0.007 3.06 0.31 0.024 0.008 13.16 6.33 0.015 Mo: 1.17 Tri: 0.10, V: 0.21 0.017 2.04 0.03 0.024 0.008 13.18 5.40 0.011 Cu: 2.03 Nb: 0.45 0.019 2.56 0.24 0.028 0.008 13.25 6.12 0.014 Cu: 0.91, W: 1.97 Tr: 0.58 0.040 1.39 0.27 0.028 0.009 12.82 6.12 0.014 Cu: 0.91, W: 1.97 Tr: 0.58 0.026<	22	0.030	0.41	0.40	0.034	0.008	13.61	6.91	0.010		Ti: 0.50, Nb: 0.4;	14.2
0.056 1.90 0.039 0.021 0.005 13.06 6.25 0.013 Tri. 0.10, V: 0.25 0.040 1.44 0.29 0.018 0.006 14.61 7.36 0.010 Cu. 1.01 Tri. 0.10, V: 0.25 0.038 1.52 0.21 0.027 0.011 13.87 7.02 0.008 Cu. 0.68, Mo: 1.02 Tri. 0.49 0.007 3.05 0.31 0.024 0.008 13.16 6.33 0.015 Mo: 1.17 Tri. 0.10, Nb: 0.41 0.013 0.32 0.012 1.218 5.40 0.011 Cu. 2.03 Nb: 0.45 0.014 0.32 0.028 0.008 1.350 7.00 0.010 W: 0.82 Tri. 0.58 0.014 0.256 0.224 0.028 0.008 1.282 6.12 0.014 Cu. 0.91, W: 0.82 Tri. 0.58 0.026 4.12 0.03 1.028 0.009 1.312 7.12 0.014 Tri. 0.91, W: 1.97 Tri. 0.81 0.026 0.21	23	0.028	0.35	0.42	0.028	9000	13.57	7.04	0.010			•
0.040 1.44 0.29 0.018 0.006 14.61 7.36 0.010 Cu: 1.01 Ti: 0.49 0.038 1.52 0.21 0.027 0.011 13.87 7.02 0.008 Cu: 0.68, Mo: 1.02 Ti: 0.10, Nb: 0.41 0.007 3.06 0.31 0.024 0.008 13.16 6.33 0.015 Mo: 1.17 Ti: 0.10, Nb: 0.41 0.007 2.04 0.30 0.032 0.012 12.18 5.40 0.011 Cu: 2.03 Nb: 0.45 0.010 2.56 0.24 0.028 0.008 13.09 7.00 0.010 W: 0.82 Tr: 0.58 0.040 1.39 0.27 0.028 0.008 12.82 6.12 0.014 Cu: 0.91, W: 1.97 Tr: 0.58 0.046 1.39 0.27 0.037 0.009 13.12 7.12 0.014 Cu: 0.91, W: 1.97 Tr: 0.58 0.046 0.31 0.21 0.004 11.72 2.42 0.009 Tr: 0.51 Nb: 0.40	54	0.056	1.90	0.39	0.021	0.005	13.06	6.25	0.013			
0.038 1.52 0.21 0.027 0.011 13.87 7.02 0.008 Cu. 0.68, Mo: 1.02 Ti: 0.37 0.007 3.05 0.31 0.024 0.008 13.16 6.33 0.015 Mo: 1.17 Ti: 0.10, Nb: 0.41 0.007 2.04 0.30 0.032 0.012 12.18 5.40 0.011 Cu. 2.03 Nb: 0.45 0.013 0.37 0.26 0.028 0.008 13.09 7.00 0.010 W: 0.82 Tr: 0.58 0.040 1.39 0.27 0.036 1.456 6.37 0.009 Co: 2.31 Al: 0.70 0.046 1.39 0.27 0.037 0.008 13.12 7.12 0.014 Cu: 0.91, W: 1.97 Tr: 0.58 0.026 4.12 0.30 0.023 0.008 13.12 7.12 0.014 Cr: 0.91, W: 1.97 Tr: 0.81 0.046 0.31 0.21 0.004 11.79 4.42 0.009 Tr: 0.27 0.014 Nb: 0.40 0.046	22	0.040	1.44	0.29	0.018	900'0	14.61	7.36	0.010	Cu: 1.01	Ti: 0.49	
0.007 3.05 0.31 0.024 0.008 13.16 6.33 0.015 Mor.1.17 Ti: 0.10, Nb: 0.41 0.007 2.04 0.30 0.032 0.012 12.18 5.40 0.011 Cu: 2.03 Nb: 0.45 0.013 0.37 0.26 0.028 0.008 13.09 7.00 0.010 W: 0.82 Tr: 0.58 0.040 1.39 0.27 0.037 0.008 1.282 6.12 0.014 Cu: 0.91, W: 1.97 Tr: 0.58 0.026 4.12 0.30 0.023 0.008 13.12 7.12 0.014 Cu: 0.91, W: 1.97 Tr: 0.51 0.035 0.21 0.16 0.023 0.008 13.12 7.12 0.014 Cu: 0.91, W: 1.97 Tr: 0.51 0.046 0.31 0.21 0.004 11.72 5.01 0.013 Nr: 0.40 0.046 0.31 0.21 0.004 11.72 5.26 0.011 Nr: 0.40 0.014 0.28 0.30 0.	92	0.038	1.52	0.21	0.027	0.011	13.87	7.02	0.008	Cu: 0.68, Mo: 1.02	Ë	16.3
0.007 2.04 0.30 0.032 0.012 12.18 5.40 0.011 Cu: 2.03 Nb: 0.45 0.013 0.37 0.26 0.028 0.008 13.09 7.00 0.010 W: 0.82 Tr: 0.58 0.040 1.39 0.27 0.037 0.008 12.82 6.12 0.014 Cu: 0.91 W: 1.97 Tr: 0.58 0.046 4.12 0.30 0.023 0.008 13.12 7.12 0.014 Cu: 0.91 W: 1.97 Tr: 0.51 0.035 0.21 0.16 0.023 0.008 13.12 7.12 0.014 Cu: 0.91 W: 1.97 Tr: 0.51 0.046 0.31 0.21 0.004 11.79 4.42 0.009 Tr:: 0.27 0.046 0.31 0.21 0.01 11.72 5.26 0.011 Nb: 0.40 0.014 0.28 0.30 0.027 0.004 11.72 5.26 0.011 0.014 0.28 1.32 0.010	27	0.007	3.05	0.31	0.024	0.008	13.16	6.33	0.015	Mo: 1.17	_	15.3
0.013 0.37 0.26 0.028 0.008 13.09 7.00 0.010 W; 0.82 Ti: 0.58 0.010 0.010 0.023	28	0.007	2.04	0.30	0.032	0.012	12.18	5.40	0.011	Cu: 2.03	Nb: 0.45	14.4
0.010 2.56 0.24 0.028 0.005 14.56 6.37 0.009 Co: 2.31 AI: 0.70 0.040 1.39 0.27 0.037 0.009 12.82 6.12 0.014 Cu: 0.91, W: 1.97 Ti: 0.81 0.026 4.12 0.30 0.023 0.008 13.12 7.12 0.014 Cu: 0.91, W: 1.97 Ti: 0.81 0.025 0.21 0.16 0.021 0.004 11.79 4.42 0.009 Ti: 0.013 0.009 0.45 0.40 0.021 0.004 11.72 5.26 0.011 0.013 0.007 0.009 0.007 0.009 0.007 0.009 0.007 0.009 0.007 0.009 0.007 0.009 0.007 0.009 0.007 0.009 0.007 0.009 0.000 0.007 0.009 0.000	က္က	0.013	0.37	0.26	0.028	0.008	13.09	7.00	0.010	W: 0.82	Ti: 0.58	14.7
0.026 4.12 0.30 0.027 0.009 12.82 6.12 0.014 Cu: 0.91, W: 1.97 Ti: 0.81 0.026 4.12 0.30 0.023 0.008 13.12 7.12 0.014 Cu: 0.91, W: 1.97 Ti: 0.81 0.026 4.12 0.30 0.023 0.008 13.12 7.12 0.014 Cu: 0.91, W: 1.97 Ti: 0.81 0.035 0.21 0.16 0.021 0.004 11.79 4.42 0.009 Tri: 0.27 0.046 0.31 0.21 0.018 0.006 11.52 5.01 0.013 ND: 0.40 0.021 0.004 11.72 5.26 0.011 ND: 0.40 0.014 0.28 13.2 0.019 0.007 10.83 3.97 0.025 0.013 0.57 1.49 0.028 0.007 17.53 7.40 0.094 0.094 0.058 0.51 1.14 0.025 0.005 17.44 7.10 0.070	ဓ္က	0.010	2.56	0.24	0.028	0.005	14.56	6.37	0.00	Co: 2.31	¥	15.1
0.026 4.12 0.30 0.023 0.008 13.12 7.12 0.014 0.035 0.21 0.16 0.021 0.004 11.79 4.42 0.009 Ti: 0.27 0.046 0.31 0.21 0.006 11.52 5.01 0.013 Nb: 0.40 0.009 0.45 0.40 0.021 0.004 11.72 5.26 0.011 0.014 0.28 1.32 0.019 0.007 10.86 3.97 0.025 0.013 0.57 1.49 0.028 0.007 17.53 7.40 0.094 0.058 0.51 1.14 0.025 0.005 17.44 7.10 0.070	=	0.040	1.39	0.27	0.037	0.003	12.82	6.12	0.014	Cu: 0.91, W: 1.97	Ë	16.1
0.035 0.21 0.16 0.021 0.004 11.79 4.42 0.009 Ti: 0.27 0.046 0.31 0.21 0.018 0.006 11.52 5.01 0.013 Nb: 0.40 0.009 0.45 0.40 0.021 0.004 11.72 5.26 0.011 Nb: 0.40 0.014 0.28 1.32 0.019 0.007 10.86 3.97 0.025 0.013 0.57 1.49 0.028 0.007 17.53 7.40 0.094 0.058 0.51 1.14 0.025 0.005 17.44 7.10 0.070	2	0.026	4.12	0.30	0.023	0.008	13.12	7.12	0.014			16.0
0.046 0.31 0.21 0.018 0.006 11.52 5.01 0.013 Nb: 0.40 0.009 0.45 0.40 0.021 0.004 11.72 5.26 0.011 Nb: 0.40 0.014 0.28 1.32 0.019 0.007 10.86 3.97 0.025 0.013 0.57 1.49 0.028 0.007 17.53 7.40 0.094 0.058 0.51 1.14 0.025 0.005 17.44 7.10 0.070	⋖	0.035	0.21	0.16	0.021	0.004	11.79	4.42	0.009		Ti: 0.27	10.5
0.009 0.45 0.40 0.021 0.004 11.72 5.26 0.011 0.014 0.28 1.32 0.019 0.007 10.86 3.97 0.025 0.013 0.57 1.49 0.028 0.007 17.53 7.40 0.094 0.058 0.51 1.14 0.025 0.005 17.44 7.10 0.070	æ	0.046	0.31	0.21	0.018	900.0	11.52	5.01	0.013		Nb: 0.40	11.1
0.014 0.28 1.32 0.019 0.007 10.86 3.97 0.025 0.013 0.57 1.49 0.028 0.007 17.53 7.40 0.094 0.058 0.51 1.14 0.025 0.005 17.44 7.10 0.070	ပ	0.00	0.45	0.40	0.021	0.004	11.72	5.26	0.011			12.1
0.013 0.57 1.49 0.028 0.007 17.53 7.40 0.094 0.058 0.51 1.14 0.025 0.005 17.44 7.10 0.070	۵	0.014	0.28	1.32	0.019	0.007	10.86	3.97	0.025			11.6
0.058 0.51 1.14 0.025 0.005 17.44 7.10 0.070	ш	0.013	0.57	1.49	0.028	0.007	17.53	7.40	0.094			20.0
	щ	0.058	0.51	1.14	0.025	0.005	17.44	7.10	0.00			19.7

TABLE 2

Mechanical properties and amount of martensite of products of the invention process and comparative products

			mar. (%)	99 888 888 886 887 77 77 87 87 87 87 87 87 87 87 87 87	9999
		7	H _v	337 337 339 301 291 293 304 304 315 320 331 331 331 331 331 331 331 331 331 33	297 300 294 307
		10 hr. ((a,	E/ (%)	2.4.0 2.4.0 2.6.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2.0 2	6.8 6.7 6.9
		600°C × 10 hr. ((a))	σ _в (kg/mm²)	110 888 888 888 888 888 888 888 888 888	9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
	Invention Process		^G 0.2 (kg/mm²)	101 202 203 204 205 205 205 205 205 205 205 205 205 205	883 821 821
	nvention	_	mar. (%)	99 27 38 88 33 36 27 38 88 38 38 38 38 38 38 38 38 38 38 38	00000
	-	(p) pəle	£	332 332 332 332 330 330 330 330 330 330	302 304 296 297
		Is Anne	(%)	8.8.7.8.7.8.7.8.7.8.8.8.8.7.8.7.8.7.8.7	7.3 7.0 7.0 7.2
		$C \times 10$ hr. (As Annealed (d).	σ _B (kg/mm²)	010 070 070 070 070 070 070 070 070 070	97 95 95 95
		2,009	$\frac{\sigma_{0.2}}{(kg/mm^2)}$	88888888888888888888888888888888888888	83 82 83
			mar. (%)	001 001 000 000 000 000 000 000 000 000	100 100 18 18
	SSG		Η	394 362 362 362 362 363 364 365 366 367 367 367 367 367 367 367 367 367	330 326 320 342 342
	nal Process	aled (d)	E/ (%)	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	5.0 5.0 5.9 26.3 5.9
•	Convention	As Anne	$\frac{\sigma_{B}}{(kg/mm^{2})}$	123 123 120 120 120 120 120 120 120 120 120 120	103 97 105 96 109
			_{σο2} (kg/mm²)	0711 0717 0717 0717 0717 0717 0717 0717	94 96 89 72 70
		Sample No.		-28489011211411111111111111111111111111111111	4 m O O iii ii.
	20			Products of the Invention Process	Compara- tive Products

TABLE 2—continued

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	mar. (%)	99 884 770 770 770 770 886 887 888 888 888 888 888 888 888 888	9999
)% Cold)	Æ	330 330 330 330 330 330 330 330 330 330	315 302 299 320
((c)) (2(E/ (%)	14.00 1.00 1.00 1.00 1.00 1.00 1.00 1.00	8.0 8.0 7.3 8.0
600°C × 10 hr. ((c)) (50% Cold)	σ _B (kg/mm²)	1100 990 990 990 990 990 990 990 990 990	103 97 98 104
109	^{σ_{0.2} (kg/mm²)}	707 708 888 888 888 888 888 888 888 888	8888 885 895
	mar. (%)	- 1822 1822 1822 1822 1832 1833 1834 1835 1835 1835 1835 1835 1835 1835 1835	0000
3% Cold,	Hv	289 289 301 301 302 302 303 203 203 203 203 203 204 204 205 205 206 207 208 207 208 208 208 208 208 208 208 208 208 208	298 305 318
((p)) (8	E/ (%)	100.00	88.3 7.3 7.3
$600^{\circ}C \times 10 hr. ((b)) (83\% Cold)$	$\frac{\sigma_B}{(kg/mm^2)}$	1000 1000 1000 1000 1000 1000 1000 100	99 94 99
)09	^{σ_{0.2} (kg/mm²)}	1 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8 8	85 89 83 87
Sample	Š	-0.64507800110164450128282828282828282828282828282828282828	∀ ⊞∪⊡⊪ir
		Steels for the Invention Process	Compara- tive Steels

· E, F: 20% cold-rolled

TABLE 3

Mechanical properties and amount of martensite of the products of the invention process and the products of the comparative process (annealed materials)

•		mar. (%)	82	82	75	72	73	75	80	84	71	68	72	92
		Hv	276	291	293	284	285	281	283	300	328	321	303	353
	600°C × 20 hr.	E1 (%)	17.3	18.4	18.5	18.0	18.9	18.7	19.3	19.1	17.4	18.5	19.4	17.3
	2.009	σ _B (kg/mm²)	84	83	90	87	90	93	88	32	117	108	96	113
		σ _{0.2} (kg/mm²)	71	75	89	75	70	72	73	85	98	82	. 78	100
		mar. (%)	96	97	6	8	97	96	96	93	90	92	. 26	92
જ		Ην	290	311	300	322	283	298	340	337	330	325	316	358
Invention Process	575°C × 5 hr.	El (%)	15.3	15.4	14.9	15.5	14.9	15.3	15.1	15.0	15.6	14.8	15.4	15.3
Inventic	275.0	бв (kg/mm²)	98	106	91	101	83	88	105	110	110	106	101	117
		_{σο2} (kg/mm²)	77	92	82	88	75	83	100	104	8	91	82	86
		mar. (%)	86	86	94	97	97	86	86	96	96	86	86	100
		Hv	286	291	290	313	287	291	322	320	334	326	300	356
	550°C × 30 hr.	EI (%)	15.7	16.1	15.4	16.4	15.8	16.8	16.1	16.0	16.3	15.7	16.9	13.3
	550°C	σ _в (kg/mm²)	82	87	83	97	. 84	82	95	66	111	110	86	119
		σ _{0.2} (kg/mm²)	74	80	75	82	75	80	83	91	84	82	87	97
	Sample		ო	4	9	တ	12	13	14	8	22	28	31	32

TABLE 3—continued

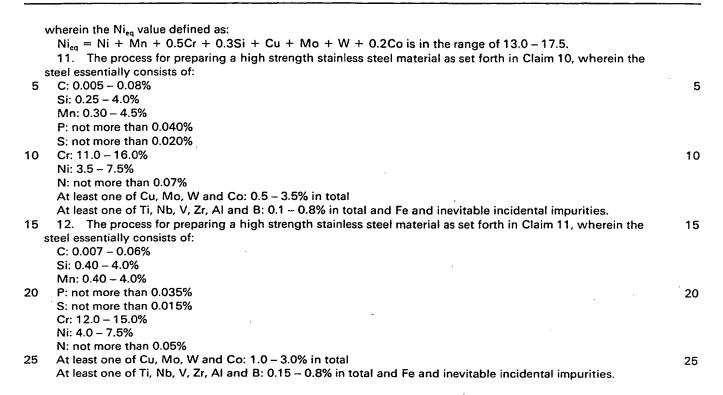
riaisj			mar. (%)	78	79	99	64	62	20	7	9/	92	83	62	20
led mate	ess		£	281	287	261	272	250	269	278	290	286	276	271	310
s (annea	ive Proc	710°C × 1 hr.	E/ (%)	11.0	10.7	11.6	10.9	12.1	11.3	12.5	10.8	11.7	10.8	12.6	9.5
ative proces.	Comparative Process	710°C	$\sigma_B = (kg/mm^2)$	88	86	82	87	81	87	82	91	110	66	82	117
the compar			σ _{0.2} (kg/mm²)	52	54	20	29	20	56	09	61	61	28	22	89
oducts of			mar. (%)	83	82	73	20	70	71	69	75	72	71	69	78
nd the pro			Ή	298	305	292	289	290	281	283	295	309	308	289	321
rocess ar		675°C × 1 hr.	E! (%)	14.9	16.3	16.9	16.4	17.5	16.3	16.9	16.4	15.9	15.7	17.0	14.0
invention p		675°C	$\sigma_B = (kg/mm^2)$	91	93	83	88	91	92	93	94	109	103	93	115
Mechanical properties and amount of martensite of the products of the invention process and the products of the comparative process (annealed materials,	Invention Process		σ _{0.2} (kg/mm²)	64	65	63	71	64	73	71	89	79	81	75	75
of the pr	Inventio		mar. (%)	80	9/	70	69	89	71	73	80	29	88	99	91
artensite			Ť	304	319	285	290	288	283	279	306	319	318	294	363
unt of mi		625°C × 1 hr.	El (%)		16.7	17.1	16.9	18.0	18.9	19.6	19.8	18.1	18.5	20.5	20.2
ies and amoi		625°C	σ _B) (kg/mm²)	93	97	87	88	85	90	82	94	114	105	90	116
nical propert			σ _{0.2} (kg/mm²) (i	67	29	65	74	89	72	74	79	83	82	74	101
Mechar		Sample No.			4	9	တ	12	13	14	18	25	28	31	32



CLAIMS

5	 Process for preparing a high strength stainless steel material having excellent workability free from weld softening consisting of a single martensitic phase or a duplex phase structure of martensite and minute austenite, said process comprising heat-treating at a temperature of 550 to 675°C for 1 to 30 hours a hot-rolled, cold-rolled or annealed material of a steel essentially consisting of: C: not more than 0.10% Si: 0.20 – 4.5% 	5
40	Mn: 0.20 – 5.0%	10
10		10
	S: not more than 0.030%	
	Cr: 10.0 – 17.0%	
	Ni: 3.0 – 8.0%	
	N: not more than 0.10%	4-
15	· · · · · · · · · · · · · · · · · · ·	15
	0.3Si + 20(C + N) is in the range of 13.0 – 17.5.	
	2. The process for preparing a high strength steel material as set forth in Claim 1, wherein the steel essentially	
	consists of:	
	C: 0.005 – 0.08%	00
20	Si: 0.25 – 4.0%	20
	Mn: 0.30 – 4.5%	
	P: not more than 0.04%	
	S: not more than 0.02%	
^-	Cr: 11.0 – 16.0%	
25		25
	N: not more than 0.07%	
	and Fe and inevitable incidental impurities.	
	3. The process for preparing a high strength steel material as set forth in Claim 2, wherein the steel essentially	
20	consists of: C: 0.007 – 0.06%	20
30	Si: 0.40 – 4.0%	30
	Mn: 0.40 – 4.0%	
	P: not more than 0.035%	
	S: not more than 0.015%	
35	Cr: 12.0 – 15.0%	35
-	Ni: 4.0 – 7.5%	33
	N: not more than 0.05%	
	and Fe and inevitable incidental impurities.	
	4. Process for preparing a high strength stainless steel material having excellent workability and free from	
40	weld softening consisting of a single martensitic phase or a duplex phase structure of martensite and minute	40
	austenite, said process comprising heat-treating at a temperature of 550 to 675°C for 1 to 30 hours a hot-rolled,	
	cold-rolled or annealed material of a steel essentially consisting of:	
	C: not more than 0.10%	
	Si: 0.2 – 4.5%	
45	Mn: 0.2 – 5.0%	45
	P: not more than 0.060%	
	S: not more than 0.030%	
	Cr: 10.0 – 17.0%	
	Ni: 3.0 – 8.0%	
50	N: not more than 0.10%	50
	At least one of Cu, Mo, W and Co: not more than 4% in total and Fe and inevitable incidental impurities,	
	wherein the Ni _{eq} value defined as:	
	$Ni_{eq} = Ni + Mn + 0.5Cr + 0.3Si + 20(C + N)$	
	+ Cu + Mo + W + 0.2Co	
55	is in the range of 13.0 – 17.5.	55
	5. The process for preparing a high strength stainless steel material as set forth in Claim 4, wherein the steel	
	essentially consists of:	
	C: 0.005 – 0.08%	
66	Si: 0.25 – 4.0%	
60	Mn: 0.30 – 4.5%	60
	P: not more than 0.04%	
	S: not more than 0.020%	
	Cr: 11.0 – 16.0% Ni: 3.5 – 7.5%	
65	N: not more than 0.07%	C.F.
00	is not more than 0.0770	65

At least one of Cu, Mo, W and Co: 0.5 - 3.5% in total and Fe and inevitable incidental impurities. 6. The process for preparing a high strength stainless steel material as set forth in Claim 5, wherein the steel essentially consists of: 5 C: 0.007 - 0.06% 5 Si: 0.40 - 4.0% Mn: 0.40 - 4.0% P: not more than 0.035% S: not more than 0.015% 10 Cr: 12.0 - 15.0% 10 Ni: 4.0 - 7.5% N: not more than 0.05% At least one of Cu, Mo, W and Co: 1.0 - 3.0% in total and Fe and inevitable incidental impurities. 7. Process for preparing a high strength stainless steel material having excellent workability and free from 15 weld softening consisting of a single martensitic phase or a duplex phase structure of martensite and minute austenite, said process comprising heat-treating at a temperature of 550 to 675°C for 1 to 30 hours a hot-rolled, cold-rolled or annealed material of a steel essentially consisting of: C: not more than 0.10% 20 Si: 0.2 - 4.5% 20 Mn: 0.2 - 5.0% P: not more than 0.060% S: not more than 0.030% Cr: 10.0 - 17.0% 25 25 Ni: 3.0 - 8.0% N: not more than 0.10% At least one of Ti, Nb, V, Zr, Al and B: not more than 1% in total and Fe and inevitable incidental impurities, wherein the Nieq value defined as: $Ni_{eq} = Ni + Mn + 0.5Cr + 0.3Si$ is in the range of 13.0 – 17.5. 8. The process for preparing a high strength stainless steel material as set forth in Claim 7, wherein the steel 30 essentially consists of: C: 0.005 - 0.08% Si: 0.25 - 4.0% Mn: 0.30 - 4.5% 35 P: not more than 0.04% S: not more than 0.02% Cr: 11.0 - 16.0% Ni: 3.5 - 7.5% N: not more than 0.07% At least one of Ti, Nb, V, Zr, Al and B: 0.1 - 0.8% in total and Fe and inevitable incidental impurities. 40 9. The process for preparing a high strength stainless steel material as set forth in Claim 8, wherein the steel essentially consists of: C: 0.007 - 0.06% Si: 0.40 - 4.0% 45 45 Mn: 0.40 - 4.0% P: not more than 0.035% S: not more than 0.015% Cr: 12.0 - 15.0% Ni: 4.0 - 7.5% 50 50 N: not more than 0.05% At least one of Ti, Nb, V, Zr, Al and B: 0.15 - 0.8% in total and Fe and inevitable incidental impurities. 10. Process for preparing a high strength stainless steel material having excellent workability and free from weld softening consisting of a single martensitic phase or a duplex phase structure of martensite and minute austenite, said process comprising heat-treating at a temperature of 550 to 675°C for 1 to 30 hours a hot-rolled, 55 55 cold-rolled or annealed material of a steel essentially consists of: C: not more than 0.10% Si: 0.20 - 4.5% Mn: 0.20 - 5.0% P: not more than 0.060% 60 S: not more than 0.030% Cr: 10.0 - 17.0% Ni: 3.0 - 8.0% N: not more than 0.10% At least one of Cu, Mo, W and Co: not more than 4% in total 65 At least one of Ti, Nb, V, Zr, Al and B; not more than 1% in total and Fe and inevitable incidental impurities. 65



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